Wear Resistant, Friction Reducing Coatings Reduce Tubing Wear in Problematic Sucker Rod Couplings Wells: Laboratory Testing and Field Trials

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The Problem

- Tubing wear from couplings can cause tubing leaks
- Fixing tubing leaks is expensive
- High failure frequency wells encounter economic challenges due to costs
Background – Coatings

- **Coating** – Diamond Like Carbon (DLC)

- **Benefits**
  - Low Friction
  - High Wear Resistance
  - Ease of application on cylindrical bodies
  - Tailored chemistry and architecture
Methods
• Test length – 450k cycles
• Stroke Length – 1 ft
• Side load applied – 74 lbs
• Spray metal coupling run in parallel as control
• Water circulated to clear debris

Measurements
• Coupling wear – measured as a change in diameter of couplings
• Tubing wear – measured as a change in tubing thickness in reference to a non-contacting region
Laboratory Testing – Coupling Wear

<table>
<thead>
<tr>
<th>Location</th>
<th>Test 1 (in)</th>
<th>Test 2 (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coating A</td>
<td>Spray-Metal</td>
</tr>
<tr>
<td>Top</td>
<td>0.0023</td>
<td>0.0028</td>
</tr>
<tr>
<td>Middle</td>
<td>0.0019</td>
<td>0.0005</td>
</tr>
<tr>
<td>Bottom</td>
<td>0.0020</td>
<td>0.0004</td>
</tr>
</tbody>
</table>
Laboratory Testing – Tubing Wear

*Coating A* – 50% reduction in wall loss

*Coating B* – Negligible tubing wall loss

<table>
<thead>
<tr>
<th>Tubing Measurements</th>
<th>Test 1 (in)</th>
<th>Test 2 (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating A</td>
<td>0.022</td>
<td>0.005</td>
</tr>
<tr>
<td>Spray-Metal</td>
<td>0.045</td>
<td>0.033</td>
</tr>
<tr>
<td>Coating B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray-Metal</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Wall loss comparison with control (%)

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating A</td>
<td>49%</td>
<td></td>
</tr>
<tr>
<td>Spray-Metal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coating B</td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td>Spray-Metal</td>
<td></td>
<td></td>
</tr>
</tbody>
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Field Trial

Wells
- > 2 tubing failures/year
- Couplings installed during tubing workover
- Rod pump depth between 6-10k ft MD

Field Trial Scope
- Install couplings in high wear locations in the rod string
- Monitor wells to observe changes in time between tubing failures

<table>
<thead>
<tr>
<th>Couplings Installed</th>
<th>Coating A</th>
<th>Coating B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 1</td>
<td>Well 2</td>
<td>Well 3</td>
</tr>
<tr>
<td>Number</td>
<td>100</td>
<td>39</td>
</tr>
<tr>
<td>Size</td>
<td>7/8&quot;</td>
<td>7/8&quot;</td>
</tr>
</tbody>
</table>
Field Trial – Coupling Wear

Well 2 suffered a rod part at 10 months, which allowed for inspection of couplings in the well when the rod string was pulled.

Coating A – Minimal wear seen after 10 months

Spray metal – Striations and removal of SM coating seen at 10 months
Field Trial – Reduction in Workovers

<table>
<thead>
<tr>
<th></th>
<th>Coating A</th>
<th>Coating B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base time between tubing failures (months)</td>
<td>Well 1: 4, Well 2: 6, Well 3: 6</td>
<td></td>
</tr>
<tr>
<td>Running time without failure with coating (months)</td>
<td>Well 1: 16, Well 2: 24, Well 3: 19</td>
<td></td>
</tr>
<tr>
<td>Factor of increase of time between workovers</td>
<td>Well 1: 4X, Well 2: 4X, Well 3: 3.2X</td>
<td></td>
</tr>
</tbody>
</table>

- No change in sucker rod pump operation during the field trial
- All wells saw a substantial increase in time between tubing failure
- During routine wellwork coupling wear could be identified by appearance change in the couplings
- Well 1 and 2 transitioned from rod pumping and never saw tubing failures
- Well 3 had significant sand present and still saw significant improvements
Field Trial – Tubing Wear

Pre-Field Trial Scan

End of Field Trial Scan

Defect Severity
- Severe (>50%)
- Significant (<50%, >25%)
- Moderate (<25%, >15%)
- Minimal (<15%)

Failure Point

Uncoated Couplings

7/8” Coated Couplings
Field Trial – Coupling Wear, Sand

- Coupling wear pattern in sand-free environment is similar to the laboratory testing.
- Coupling coating wear is more significant in sandy wells and doesn’t mimic lab findings.
- Even with sand present, Coating B offered a tubing wear benefit.
Laboratory testing demonstrated a reduction in tubing and coupling wear through use of DLC, friction reducing coatings.

Reduction in tubing wear translated to drastic increases in tubing life between workovers in all three wells evaluated as a part of the field trial.

For sucker rod wells with high frequency, high cost tubing failures, targeted use of coated couplings can be an effective technology to reduce OPEX.
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